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AN EXAMINATION OF SOUTH AMERICAN SNOW COVER EXTENT AND SNOW MASS FROM 1979-2002 USING PASSIVE MICROWAVE SATELLITE DATA

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1. INTRODUCTION

Exclusive of Antarctica, seasonal snow in the Southern Hemisphere is, for the most part, confined to South America. Though snow may fall and even persist on the ground for several days in Africa and Australia, on those continents, snow is basically a novelty. Using data from the SSMR instrument on board the Nimbus-7 satellite and from the SSMI sensors on board DMSP satellites, seasonal snow extent and snow depth (snow mass) have been calculated for the period from 1979-2001 in the middle latitudes of South America. The objectives of this study are to measure the seasonal snow cover and snow mass during the late fall and winter months using passive microwave satellite data. Using this data, a snow record will be generated that is comparable to the snow record for North America and Eurasia.

2. STUDY AREA

In the Patagonia region of Argentina and the Tierra del Fuego region of Argentina and Chile, snow may accumulate as early as May and as late as October. Each winter, snow is a regular feature south of about 45 degrees latitude, and in the snowiest years, snow can cover the ground for several weeks in succession. A single storm may cover the ground with several hundred thousand km² of snow. Snow can fall at locations much further north than expected, and it can even lay on the ground for a few days as far north as 27 degrees south latitude. Snow here is usually confined to elevations greater than 1,000 meters above sea level (Prohaska, 1976). However, in most seasons, the non mountainous snow cover varies from year-to-year. This is to be expected when accumulations are shallow.

3. PASSIVE MICROWAVE DATA

The SMMR instrument operated from November 1978 until August of 1987. The first SSMI was launched in late 1987, thus there is no overlap period for these two sensors, and therefore a serious validation between them is lacking.

Whereas SMMR was fitted with an 18 GHz sensor, a 19 GHz sensor was employed on the SSMIs. The nominal resolution for the 19 GHz (actually 19.35 GHz) channel is $69 \times 43 \text{ km}^2$ and for the 37 GHz channel it is $37 \times 28 \text{ km}^2$. For this investigation, brightness temperature differences between the 19 GHz (for SSMI) and 37 GHz channels were multiplied by a coefficient related to the average grain size (4.8 for SSMI and 4.77 for SMMR) to derive the snow water equivalent of snow (Chang at al., 1987). The simple algorithm is then

where SWE is snow water equivalent in mm, and 19 GHz and 37 GHz are the brightness temperatures at 19 GHz and 37 GHz vertical polarizations, respectively. If the 18 GHz channel is less than the 37 GHz channel, then the SWE is defined to be zero.

To derive snow depth, the above algorithm can be divided by 3.0 – the average density of mid winter, mid latitude snowpacks is approximately $300~{\rm kg}\text{-}^3$. This is expressed as follows:

SD = 1.6 [(19 GHz - 37 GHz) - 5] cm [2]

Where SD is snow depth in cm, and 19 GHz and 37 GHz are the brightness temperatures at 19 GHz and 37 GHz vertical polarizations, respectively.

Using data from a study by Van Der Veen and Jezek (1993), it was found that a -5 K offset exists between SMMR data and SSMI observations over Antarctica. The above equations for the SSMI include this offset. For SMMR, however, this offset was not used.

Passive microwave remote sensing is particularly advantageous in Patagonia, not only because clouds and darkness do not preclude snow detection, but also because Patagonia has few forests. The emission from trees can confound the scattering signal of snowpacks, and thus if forests are present, adjustments would need to be made to the retrieval algorithms in order to account for the forest emission and resulting increase in brightness temperature.

4. DATA ANALYSIS

SSMR and SSMI snow data were acquired from May through August for the years 1979-2001. Note, that 1999 data have not as yet been processed due to a programming problem. In order to construct snow maps, 19 GHz (18GHz in the case of SMMR) and 37 GHz (horizontal) radiances were converted to brightness temperatures. Both average monthly and monthly maximum maps of snow cover extent and snow depth (mass) were generated for the period using equations 1 and 2. Average monthly snow depth is given as 1/2 of the maximum observed on any day. Thus, if 24 mm of snow was the maximum daily snow for any given pixel during the month, the average snow depth for the month was 12 mm. This procedure was used because, while the snow in Patagonia is generally quite shallow and transient, the snow thickness seems to be rather consistent - pixel-to-pixel variance is low.